TEM and EELS investigations of soot particles directly from the combustion chamber of low emission Diesel engines

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Diesel soot is formed during the combustion of fossil fuels and is known as one of the main environmental pollutants [1, 2]. The soot from the exhaust of Diesel engines typically consists of soot particles a few tens of nanometers in size which form chainlike aggregates. The improvement of combustion processes and aftertreatment strategies, such as particulate traps, are possibilities to reduce the soot emission. Therefore, it is important to understand the particulate formation processes and destruction mechanisms.

The soot particles are known as onion-like structures, consisting of an inner core and an outer shell. In the outer shell, curved graphene layers concentrically surround the inner core [3]. Fullerenes like C_{60} may form the nucleus of soot particles, which are growing via addition of molecules from the gas phase. The growing mechanisms are dominated by diffusion properties of carbon clusters, which can be controlled by the temperature and pressure in the combustion chamber. Several phenomenological models have been presented to understand the complex soot formation processes [4, 5]. However, the formation mechanism is still not completely understood.

In this work, we present a new technique to collect soot particles directly from the combustion chamber (Fig. 1). By this technique it is possible to gather soot samples in the range of milliseconds after injection begin of the Diesel fuel. To achieve this, a gas sampling probe head is being introduced in the combustion chamber, while the inlet and outlet valves are closed. The probe collects soot from the diffusion flame, which is then deposited on grids for TEM and EELS investigations. The aim is to investigate the morphology and inner structure of soot particles in the early formation stages.

Soot samples for TEM and EELS analysis have been taken at three different collecting times, namely 3.3, 4.2 and 33 msec after injection begin, respectively. The TEM investigations reveal significant changes in the morphology and inner structure of the soot particles. The sample taken 3.3 msec after injection begin shows compact agglomerates (Figure 2 a)), containing very fine fullerenic particles on the edges (Figure 2 b)). 4.2 msec after injection begin (Figure 2 c)), the fullerenic particles have already grown to nascent soot particles (Figure 2 d)), which are also packed in compact aggregates. The sample taken 33 msec after injection begin (Figure 2 e) + f)) shows soot particles, which have increased in size and are comparable with soot particles in exhaust soot. EELS measurements (Figure 2 g)) indicate changes in the electronic structure, which can be correlated with the TEM observations. The strong increase of the π^*-peak (sp^2-bonded carbon) of the soot samples at 4.2 and 33 msec, in comparison with the sample at 3.3 msec after injection begin, can be assigned to the time dependent growth of the soot particles.

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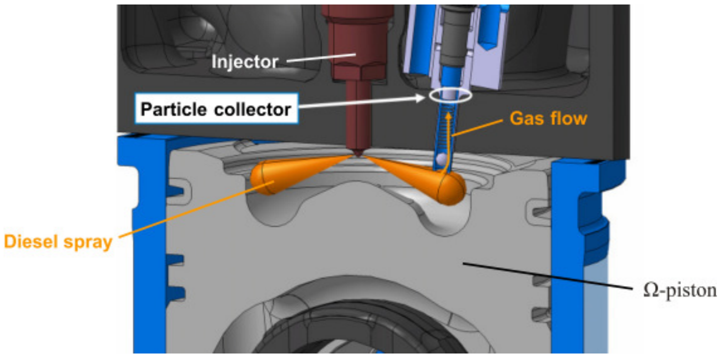

Figure 1. Gas sampling probe head for collection of soot particles directly from the combustion chamber of a Diesel engine.

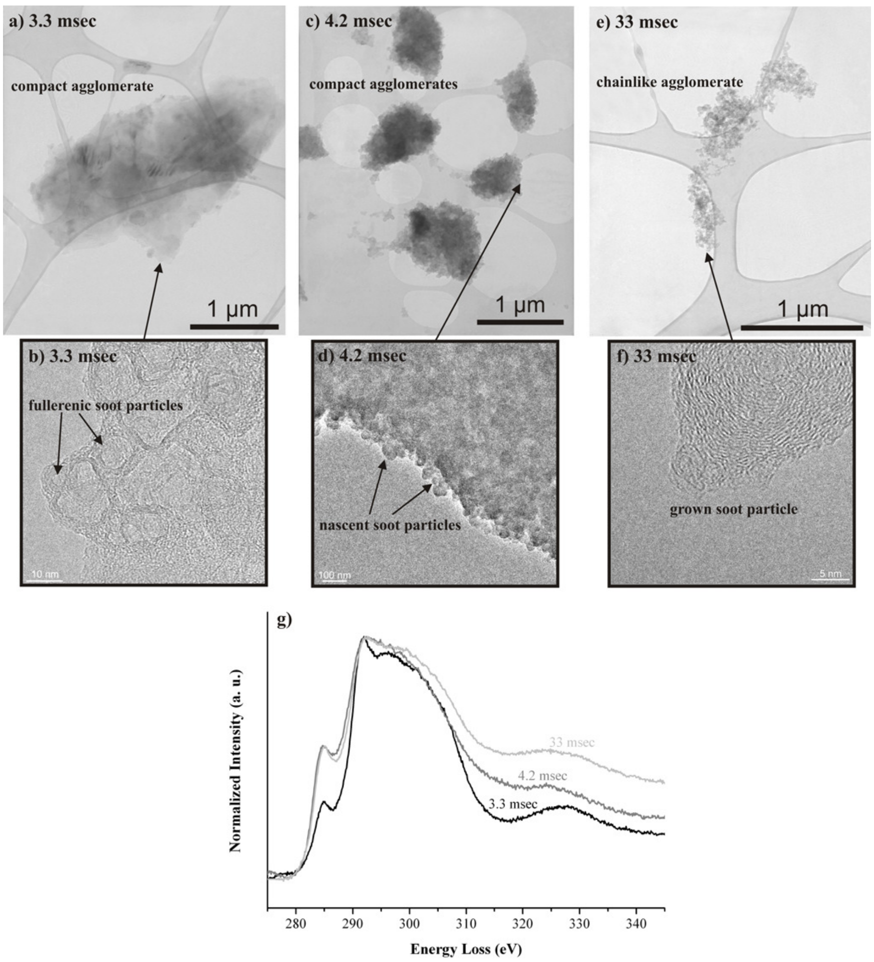

Figure 2. a) – f) TEM and HRTEM images and g) EELS spectra of soot particles, collected directly from the combustion chamber of a Diesel engine, at different times after injection begin: a) + b) 3.3 msec, c) + d) 4.2 msec, and e) + f) 33 msec, respectively.

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